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Christmas Tree Production Using the Runoff Farming System

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Abstract. **Runoff farming was used to produce Eldarica pine (*Pinus eldarica* Medw.) and Arizona cypress (*Cupressus arizonica* Green) as Christmas trees in a semiarid, 300-mm precipitation zone in Arizona. Natural precipitation was supplemented with runoff from treated, noncropped catchment-terraces adjoining the cropping area. Catchement treatments were wax (0.5 kg·m^{-2}) on a sandy soil and sodium chloride salt (1.1 kg·m^{-2}) on a clay soil. Terrace widths were varied to provide the crop an estimated 2, 3, and 4 times the precipitation. Trees were hand-watered from March to August the first year to ensure establishment. Regardless of terrace width, 90% of the cypress on the wax site were marketable in 3 years, and 90% of the pines on the salt site were marketable in 4 years. The other 2 tree–treatment combinations were less successful because of soil–species interrelated problems.**

New high-value crops that tolerate reduced amounts or quality of water are needed for the arid and semiarid southwestern United States, where many traditional irrigated crops are no longer profitable. Christmas trees could be one such new crop. Although 20,000 ha of Christmas trees are grown throughout the United States (5), most trees sold in the Southwest are still imported.

Christmas trees have several advantages as a potential high-value crop for the Southwest, e.g., the crop uses little water. Eldarica pine, a relatively new tree in commercial production, used less than 600 mm of irrigation in New Mexico in the 3rd year of growth, (the year of harvest), and considerably less than that the 2 previous years (4). The crop, when managed correctly, is of high value. Freshness; low transportation costs; the possibility for choose-and-cut, live-tree, and nursery stock sales all further improve the profit potential for locally grown trees. Furthermore, local markets and a marketing structure already exist for Christmas trees.

The objective of this study was to evaluate growing a high-value crop in a semiarid climate using runoff farming. With this farming system, the inadequate precipitation is supplemented with runoff water from noncropped catchment areas (3). No irrigation is used. The combined precipitation and runoff water is stored in the soil profile of the cropping area.

Two study sites were selected near Camp Verde, Ariz. on the Prescott National Forest (elevation 950 m). Climate is semiarid—precipitation averages 300 mm per year, but potential yearly evaporation is 5 times that. There are both winter and summer rainy seasons, but only 10% of the rainfall normally falls during the critical spring growing season (April through June). Indigenous desert scrub vegetation occupying both sites includes creosotebush [*Larrea tridentata* (DC.) Coville], catclaw (*Acacia greggii* Gray), various cacti, and many annual and perennial weed species.

Soil at the sand site was classified in the Cornville series as a loamy sand, mixed, thermic Typic Haplargids with 79%, 13%, and 8% sand, silt, and clay, respectively. Soil at the clay site was classified in the Glendale series as a silty loam, mixed (calcareous), thermic Typic Torrifluvents with 11%, 76%, and 13% sand, silt, and clay, respectively.

Installation procedures and cultural practices were detailed previously (2). Six 37.5 m long parallel-contour terraces were constructed at each site with a patrol grader. The upper terrace areas (catchments) collected the precipitation and funneled the runoff to the 1.5-m wide, back-sloped cropping areas. The catchment portions of the duplicate sets of terraces on the sand site were 1.5, 3.0, and 4.5 m wide (ratio of runoff to run-on areas of 1:1, 2:1, and 3:1). Clay site catchments were twice as wide (ratios of 2:1, 4:1, and 6:1). Our intent was to provide the cropping areas with 600, 900, and 1200 mm of total water, if spread uniformly over the 1.5 m wide cropping area, assuming 100% and 50% runoff efficiencies (runoff/precipitation) from treated sand and clay site catchment, respectively.

After shaping and smoothing, the catchments on the clay site were treated with 11,000 kg·ha^{-1} of NaCl stock salt (1), tilled into the top 5 cm of soil. Sand site catchments were treated the 2nd summer, after the weeds were under control, first with polyvinyl acetate as a soil stabilizer and 2nd with a residual wax containing 2% antistripping agent (2) sprayed on as a hot melt at 0.5 kg·m^{-2}. The reverse combinations (salt on sand and wax on clay) are not feasible treatments.

Containerized seedlings were planted 15 Mar. 1979. Trees were spaced 1.5 m apart, 25 per row, located midway up the 1.5-m wide, untreated back-sloped bottom portion of the terraces. One set of 3 terraces at each site was planted with Eldarica pine, the other with Arizona cypress (*Cupressus arizonica* Green). Trees were hand-watered until the summer rainy season began in August. Thereafter, they received only water from the runoff-farming system.

Precipitation was measured at the nearby Forest Service weather station and at each

Fig. 1. Three-year-old Arizona cypress grown in a 300-mm precipitation zone using runoff farming.

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Table 1. Estimated available water from runoff-farming system.

	Clay site					Sand site				
		Run-	H_2O delivered (mm)				Run-	H_2O delivered (mm)		
	Precip.[z]	off	Catchment ratios			Precip.[y]	off	Catchment ratios		
Yr	(mm)	(%)	2:1	4:1	6:1	(mm)	(%)	1:1	2:1	3:1
1980	328	48	650	960	1280	338	34	460	580	700
1981	337	57	721	1100	1490	345	63	560	780	1000
1982	438	39	780	1120	1460	455	60	730	1000	1270
1983	422	42	780	1130	1490	415	60	660	910	1160

[z]In 1979 the yearly precipitation at the ranger station was 325 mm, of which 125 mm fell after hand-watering of the trees was stopped on 2 Aug. Precipitation data shown for years 1980–1983 is from rain gauges located on-site.
[y]Sand plot was treated with wax in Aug. 1981. Runoff estimates for sand plot for 1982 and 1983 are based on sprinkler data rather than from the runoff-monitoring plot.

site. Runoff was estimated from a small, similarly treated, monitored catchment plot at each site. Soil moisture was determined monthly to 160 cm depth on each row of trees with a neutron probe. Tree heights were measured monthly. Harvestable trees were cut each December, beginning the 3rd year, using the stump-culture technique.

Rainfall was above average every year (Table 1). Runoff efficiency (runoff/precipitation) on the salt-treated clay catchments was about 50%, as expected. Total water delivered to the 3 sized catchments exceeded the 600, 900, and 1200 mm expected each year. Runoff efficiency of the catchments on the sand site was less than predicted because of weed problems. The total amount delivered was below expectation in 1980 when trees were small, but was near the predicted amounts in subsequent years because of above-average precipitation.

Cypress on the sand site doubled in height each of the first 2 years and averaged more than 2 m by December of the 3rd year. Nearly 90% of these cypress trees were of marketable size (1.5 m), so the site was clear-cut (Table 2). The 2:1 and 3:1 ratio rows produced slightly larger trees than the 1:1 row, but the additional growth did not offset the benefit of the high-planting density. These Arizona cypress presented an impressive, uniform stand (Fig. 1), indicating that water harvesting could be used to develop windbreaks, landscape plantings, wildlife habitat, and fuel wood in addition to Christmas trees.

Pines on the clay site merely survived the first year, which put them a year behind the cypress. However, these pines more than doubled in height each of the next 2 years, so that 24% of them reached marketable size in only 3 growing seasons (Table 2). By December of the 4th year, 64% more of these Eldarica pine were marketable (88% total in 4 years). All of the surviving pines on the 2 largest catchments (4:1 and 6:1) were marketable in 4 years, whereas 76% of those on the small 2:1 catchment were harvestable. Height of these trees after 3 years was not significantly related to the amount of runoff water received; but, by year 4, the driest treatment had a considerably greater number of undersized trees. Undoubtedly, evaporative demand by the large trees during year 4 finally exceeded the available water supply during part of the growing season.

There are reports (4) of Eldarica pines attaining marketable size in only 2 to 3 years in the Southwest with irrigation. If seedling establishment could be accelerated under the runoff farming system, most of the pines in the runoff system should be marketable in 3 years. Also, our preliminary efforts with stump culturing suggest that a 2nd crop can be harvested in only 2 years; i.e., 2 crops of pines in 5 to 6 years using runoff farming as the only water source. Growth and quality should improve as expertise is gained with this new cultural system and its associated agricultural practices.

The other 2 tree–site combinations (pines on sand and cypress on clay) were not as successful. Both species grew as fast as their counterparts the first year, and mortality rates were low (3% to 4%), but the pines on the 2 smaller terraces of the sand site suffered more than 50% mortality the 2nd and 3rd summers (Table 2). Soil moisture data, obtained with a neutron probe, showed that these pines required 4 years to root below 100 cm, but cypress at this site had rooted below 100 cm by July of the 2nd year and below 160 cm by year 3. The Eldarica pines survived and thrived once they had rooted deeply, and those on the largest (3:1) catchment yielded 76% marketable trees in 5 years. Several deep-till methods on the sand site are now being investigated for improving rooting of Eldarica pine seedlings.

Table 2. Disposition of Christmas trees.

				Accumulative dispositive (%)[z]				
		No.	Catchment	Marketable				
Tree	Treatment	trees	ratios	Yr 3	Yr 4	Yr 5	Died	Culls
Cypress	Wax	75	---[y]	89[x]	89	89	3	8
Pine	Salt	75	---[y]	24	88	92	4	4
Cypress	Salt	75	---[y]	24	24	29	3	68
Pine	Wax	25	1:1	4	16	44	52	4
		25	2:1	0	8	32	68	0
		25	3:1	28	52	76	20	4

[z]Any difference greater than 29.5% in a column, based on 25 trees and representing one catchment ratio, is statistically significant ($P \leq 0.05$) using binomial confidence intervals. If differences among the 3 terraces of any one tree–treatment combination were less than 29.5%, results for that combination were averaged.
[y]Results for the 3 terraces averaged.
[x]Clear cut in year 3.

Table 3. Estimated yearly Christmas tree harvests at Camp Verde based on catchment sizes (planting densities), rotation time, and estimated percentage of marketability.

Catchment ratio; treatment	Density ($trees \cdot ha^{-1}$)	Yearly harvest[z] ($trees \cdot ha^{-1} \cdot yr - 1$)
		3 yr rotation
1:1; wax	2220	700
2:1; wax	1480	470
3:1; wax	1110	350
		4 yr rotation
2:1; salt	1480	280 (350)
4:1; salt	890	210
6:1; salt	630	150
Northern grown solid stand[y]	2545	
5-year rotation		480
10-year rotation		240

[z]95% marketability assumed for all stands except 75% for pine on the 2:1 sodium salt treatment. The number in parenthesis (350) is the number of marketable trees expected if supplemental irrigation were added to the runoff system during the fourth year.
[y]Planting density for 2 × 2 m spacing.

Cypress trees on the clay site also grew poorly. Only 29% of them reached marketable size and quality in 5 years (Table 2). The rest had to be classified as cull Christmas trees. Neutron moisture data showed that the cypress roots quickly exploited deep-stored soil moisture, but the trees became stunted as surface sealing drastically reduced infiltration. Surprisingly, the pine thrived under identical conditions.

One of the criticisms of runoff farming is that so much land must be sacrificed for catchment area. Table 3 lists the planting densities for the several ratios of runoff to run-on areas used in this study. It also shows a typical solid-stand density recommended for rain-fed conditions in northern states. The important number, however, is how many trees are harvestable per hectare per year with a typical rotation. The 1:1 ratio produced 700 cypress trees per year with a 3-year rotation. The number dropped as catchment ratio and time to maturity increased.

For the Eldarica pines, doubling the catchment sizes on the clay site, compared to the sand site, and adding a 4th year of growth markedly reduced the yield of marketable trees per year. However, one must remember that this land in its natural state produces practically nothing of economic value. Christmas trees are grown in northern states in dense stands, but growth rate is slower than in Arizona. With the right species, under the right rainfall catchment treatment, it should be possible to grow more Christmas trees per year per unit area with runoff farming in the semiarid Southwest than conventionally in the humid north.

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Effect of Flowers on Stem Elongation in Easter Lily

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Abstract. **Internode elongation in lily (*Lilium longiflorum* Thunb.) increased significantly in the uppermost internodes during the development of the flowers. The last 4 internodes contributed as much to plant height as the first 30 internodes. Removal of the flowers reduced internode elongation, and within the range of 1–4 flowers per plant, length of the uppermost internodes was directly related to flower number. Removal of the perianth of the flowers was almost as effective as defloration in reducing internode growth. Application of gibberellic acid to decapitated stems completely replaced the effect of the flowers, whereas indoleacetic acid was only partially effective in restoring internode growth.**

Height control is one of the most important components in the commercial production of Easter lily. Plant height may be affected by a number of environmental and genetic factors, as well as by cultural practices and the application of growth-regulating chemicals. Kohl and Nelson (3), for example, found that both light intensity and photoperiod affected plant height. The combination of long days and low light (16 hr, 69 μmol·s^{-1}·m^{-2}) resulted in the greatest stem growth, while the least growth occurred under short days and high light (8 hr, 138 μmol·s^{-1}·m^{-2}). Interrupting the night period with incandescent light can also lead to increased stem growth (6).

Day temperature is another factor affecting stem elongation. Roh and Wilkins (5) reported that forcing temperatures above 21°C led to greater stem elongation than lower temperatures.

Plant height in vernalized bulbs is usually a function of internode length rather than the number of leaves produced before floral initiation (6). The process of internode elongation in lily can be controlled by plant growth regulators. For example, GA_3 and GA_{4+7} increase internode length (1), whereas ancymidol reduces internode length and plant height (8).

The presence of floral organs can also influence height in bulbous plants. Removal of the flower from tulip or narcissus resulted in a marked reduction in floral stalk elongation (2, 4). There is little information, however, on the role of the flower in stem elongation in lily. In this report we describe the effect of flower number and flower removal on stem growth and an attempt to replace the effect of flowers by application of plant growth regulators to deflorated stems.

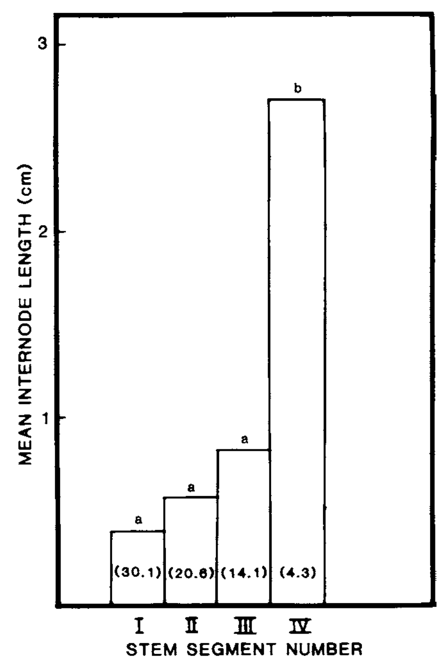

Fig. 1. Mean internode length in relation to node position on Easter lily stem. The stem was divided into 4 equal segments. I = basal segment, IV = final segment before flowers. Numbers in parentheses refer to mean node number in each segment. Mean separation by Tukey's HSD. (P = 0.05, n = 10).

Cultural practices. Vernalized Easter lily bulbs ('Ace') were obtained from a commercial source and grown in 15-cm plastic pots in a mix consisting of 50% sphagnum peat, 40% Styrofoam, and 10% coarse sand (by volume), amended with 4 kg dolomitic lime, 0.03 kg Fe, and 0.054 kg granular Aqua-Gro per yard^3. Plants were grown on a single greenhouse bench at 15°C night and 20° day temperature, and fertilized with 200 mg·liter^{-1} N (15N–6.6P–12.5K) at each watering. One watering per week was given without fertilizer.

Measurement of internode length. Lily stems were cut at the soil surface at the con-

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